ANISEIKONIA—A FACTOR IN THE FUNCTIONING OF VISION

BY

ADELBERT AMES, JR.

Reprinted from
American Journal of Ophthalmology
Vol. 18, No. 11, November, 1935

Hy2330
.A44 1935

AMERICAN FOUNDATION
FOR THE BLIND INC.

HV2330
A
cop 1

ANISEIKONIA—A FACTOR IN THE FUNCTIONING OF VISION

BY

ADELBERT AMES, JR.

Reprinted from
American Journal of Ophthalmology
Vol. 18, No. 11, November, 1935

ANISEIKONIA—A FACTOR IN THE FUNCTIONING OF VISION

Adelbert Ames, Jr., M.A.
HANOVER, NEW HAMPSHIRE

Through disparity in the size of ocular images, the interpretation, by means of stereoscopic vision, of the position of surfaces and planes or groups of objects taken as a whole is affected. The resulting misinterpretations are demonstrable on an instrument called the Tilting Field. Disparity in the size of ocular images, on the other hand, affects the perspective vision very slightly, if at all, and allows correct interpretation of such objects. Thus the extent to which total visual judgment is affected by false stereoscopic sense will depend upon the predominance of perspective features in the field of view. From the Department of Research in Physiological Optics, Dartmouth Medical School. Read before the American Association for Research in Ophthalmology, at Atlantic City, June 11, 1935.

In general, vision is the sensory function upon which we rely to inform us of the nature and position of objects that surround us. The nature and characteristics of particular objects we recognize through the visual capacity to differentiate detail. The spatial relationship of objects to one another and to ourselves is made known to us principally in two ways: first, through perspective; second, through our stereoscopic sense.

Our perspective sense is based on the relative size, shape, and positioning of the images of the various objects in the visual pictures that reach our consciousness. In general, the directional position of objects is given by their lateral and vertical disposition; their distance by the relative apparent sizes of objects of known size. For example, if we see two objects which we know are the same size, we know that the one that appears smaller is farther away. This is called perception by perspective. If, through experience, we have an accurate knowledge of the actual size of the objects about us we have a most exact sense of the distribution of those objects in the three dimensions of space. So, when looking down a familiar street, we know very accurately the position of the various buildings and their parts and that of any persons who may be on the street. The exactness of such placing is evidenced by the fact that by the art of perspective a view in elevation can be translated into a view in plan.

The second and next most important way by which we are cognizant of the distribution of objects and surfaces in space is through our stereoscopic sense. Due to the separation of our two eyes, when we look at a field with objects at different distances, the pictures that come to consciousness through each eye are slightly different. The slight disparities of the placing of the images of the same objects tell us the relative distances of the objects.

In figure 1, A and B are two objects in space at different distances from the observer whose right and left eyes are shown at R.E. and L.E. If the observer fixates the nearer object, A, images of A will be formed on the fovea of each eye at F_R and F_L. Images of the point B will be formed at B_R on the retina of the right eye and B_L on the retina of the left eye. As is evident, these similar images will be formed at disparate points on the two retinas. For the purpose of demonstration they will be placed in a particular manner relative to intermediate corresponding retinal points; for example, C_R and C_L; the position of the image in the right eye (B_R) being slightly to the left of the corresponding point, C_R, while the image (B_L) in the left eye lies at a greater distance to the right of the corresponding point, C_L. This disparity is translated into difference in distance and the object B appears as a single object farther away than the object A.

Similarly, in figure 2, when the object D is to the left of and nearer than A, the image, D_R, in the right eye lies to the right and nearer the corresponding point, C_R, and the image, D_L, in the left eye lies to the left and farther from the corresponding point, C_L. The particular nature and amount of this disparity is translated into difference in distance such that in this case the object D appears as a single object nearer than the object A.

In general, with near objects, the farther the objects B and D are in front of or behind A, the greater this disparity will be; the nearer, the less. The normal threshold sensitivity for this disparity is very low, about ten seconds of arc (10″), so that our stereoscopic judgment of depth is very accurate.

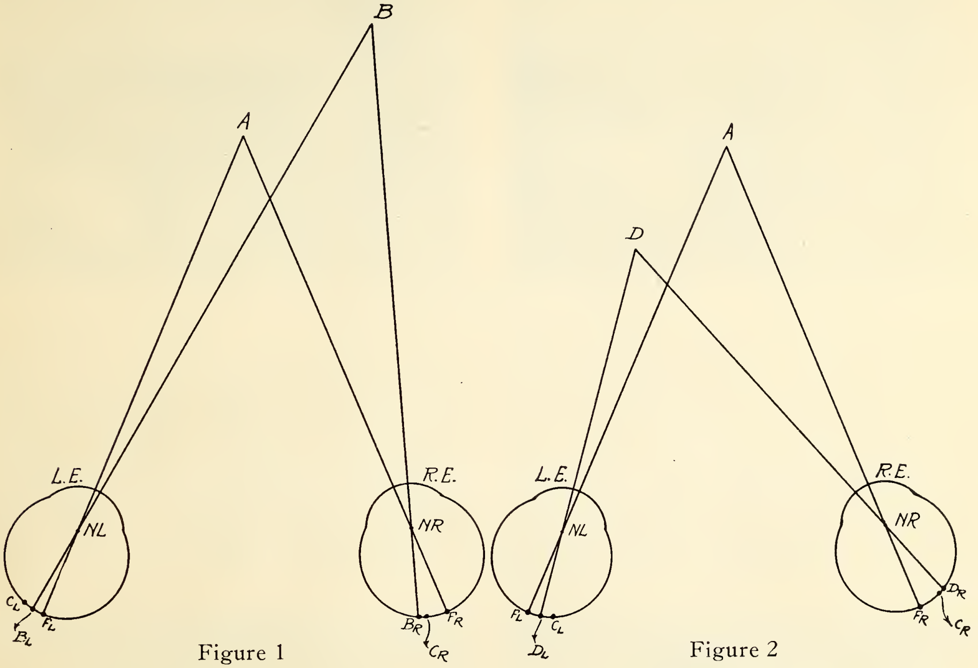

Figure 1

Figure 2

Figs. 1 and 2 (Ames). Schematic drawings to demonstrate the visual mechanism for judging disparity of distance in objects.

The importance of stereoscopic judgment in the functioning of vision is universally recognized, as is evidenced by the general use of stereoscopic tests in clinical practice, especially for aviators.

A great deal of attention has been paid to stereoscopic vision in its bearing on the capacity to judge correctly the relative distance, one from another, of various objects in the field of view.

It has not been generally recognized, however, that stereoscopic vision is also of the greatest importance as affecting our visual judgment of the position of groups of objects taken as a whole, planes or surfaces; that is, the bearing of stereoscopic vision as affecting our judgment of extended fields of view rather than foveal or parafoveal imaged objects only.

For instance, does the ground on which we walk appear to be in the plane in which it actually is? This may be of great importance, for example, to some of you as golfers especially in putting, and of a good deal more importance possibly, to aviators when landing on a field. Is the book which you see as straight, actually tipped or straight?

It is this important type of visual interpretation that is affected by aniseikonia, i.e., the relative size and shape of our ocular images, and also by the declinations of the retinal meridians.

This is explained as follows. In figure 1, the particular distance that the object B will be seen behind A depends upon the particular disparity of the images B_R and B_L from the corresponding retinal points C_R and C_L. If for some reason the size of the ocular image of the right eye is changed from that of the left, this particular disparity will be changed and B will appear either nearer or farther from A; nearer if the ocular image in the horizontal meridian of the right eye is smaller than that of the left, farther if it is larger. In figure 2, an increase of the ocular image of the right eye makes D appear farther away from A and a decrease makes it appear nearer. As a result, if the eyes were looking at three points in a row, a change in the size of the ocular images would cause them to appear as rotated about the center point.

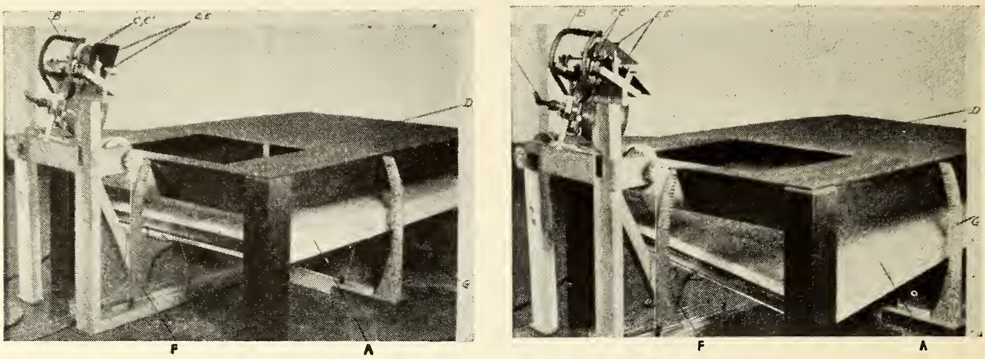

Fig. 3 (Ames). The Tilting Field, designed to measure the apparent position of a surface as judged by stereoscopic vision only.

This is a general description of the effect of aniseikonia on the horopter which has been set forth in detail in earlier work[1].

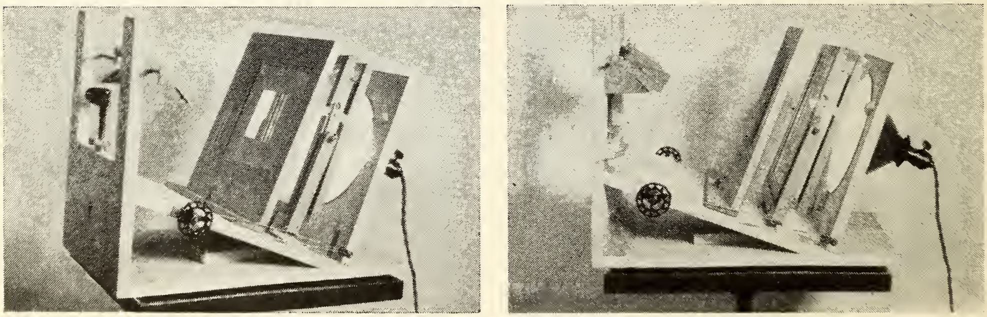

Fig. 4 (Ames). A similar instrument designed on similar principles to make the same tests at reading distance.

If instead of looking at only three objects, as A and B and D, we look at a rough surface, the apparent position of this surface, as judged by stereoscopic vision, will be determined by the nature and amount of aniseikonia which the observer may have.

This effect of changing the relative size or declinations of the ocular images can be demonstrated on the instrument which we have called a "Tilting Field" (see figure 3). This instrument was designed to measure the apparent position of a surface as judged by stereoscopic vision solely, using as a standard of reference the position of another surface as judged by perspective vision. In essence it consists of a surface, A, pivoted at its center, and free to rotate in all directions about the pivot.

There must be detail on this surface, irregular in its pattern, the surface of which is preferably raised or in relief. There is a head-positioning feature, B, with lens holders, C, C′. There is a frame, D, which serves a double purpose: it screens the edges of the tilting surface, A, from the eyes, and acts as a reference surface to which the tilting surface, A, is set parallel. There are screens, E, E′, which can be swung up before each eye and which, while allowing the eye to see the tilting field, prevent it from seeing the frame, D. There are scales, F and G, from which the amount of tilting can be read. Four degrees on the scale represents a tipping produced by about 1 percent difference in size of the ocular images. (In figure 4 is a smaller instrument designed on similar principles and used for the same tests at the reading distance.)

Referring to figure 3, an observer looking at this set-up will see with one eye the frame, D, and the tilting surface, A, through the opening of the frame. With the other eye he will see only the tilting surface, A. Binocularly he will be able to judge the position of the tilting surface, A, by stereoscopic vision only, entirely free from perspective influences. At the same time the observer will see with one eye the rectangular frame, D, in its surrounding background, the position of which is very definitely known through perspective perception. The test consists in setting the tilting surface, A, parallel to the frame, D.

In general an observer with normal eyes will set the tilting surface parallel to the frame. A person with aniseikonia will not. The extent to which he sets it away from parallel conforms very closely to the nature and magnitude of his aniseikonia.

The effect of difference in size and shape of the ocular images on the apparent position of such a surface can be very easily demonstrated by changing the size of the ocular images artificially by inserting different size lenses before the observer's eyes.

The magnitude of the stereoscopic misinterpretations of the position of surfaces resulting from aniseikonic differences is very considerable. On the Tilting Field illustrated, an induced aniseikonic difference of 1 percent in the horizontal meridian will cause an apparent tipping of about 4 degrees.

Any person with aniseikonia is subject to such stereoscopic misinterpretations, especially when perspective features in the field of view are lacking. Since such perspective features are often lacking in the field of view as seen from an airplane, the presence or absence of aniseikonia may be of vital importance to aviators.

Difference in size of the ocular images in the horizontal meridian causes the observer to interpret the field as tipped laterally. The magnitude of this tipping is quite accurately in agreement with the rotation of the longitudinal horopter resulting from the effect of iseikonic lenses.

Theoretically, an artificially produced change in the size of the ocular images in the vertical meridian only, should have no effect on stereoscopic interpretation because the disparity is not in the direction of the separation of the eyes. It has been found empirically, however, that such an increase in the vertical meridian of one eye does effect the apparent lateral tipping. The amount of this effect on observers who have no vertical size difference is as if the horizontal meridian of the other eye were increased by about half of the vertical size change produced in the first eye. It is very interesting that if the observer has a vertical size difference, a size lens correcting this vertical difference does not produce such a lateral tipping. Vertical size differences can be determined on this instrument by making use of this phenomenon.

Artificially produced relative size differences in the oblique meridians cause not only a lateral tipping, but also an apparent rotation about an axis parallel to a line connecting the centers of rotation of the two eyes, resulting from the change in the vertical declinations of the eyes which is associated with such a meridional increase in size.

This latter rotation is the same phenomenon as the apparent tipping that results when two monocularly seen vertical diameters are slightly rotated relative to each other. But there is associated with this rotation another very interesting phenomenon less well known. If, when looking down obliquely on the horizontal stereoscopic field, the vertical meridians of the observer's dioptric images are rotated by means of lenses in a disclination direction from corresponding vertical meridians, the stereoscopically seen surface appears to move away from the observer. When rotated in a conclination direction it appears to move nearer to the observer. But if a horizontal stereoscopic field is looked at from below, just the reverse effect is produced. If a vertical stereoscopic field is used, no such effect is apparent.

This phenomenon of change in the apparent distance of stereoscopically judged inclined surfaces with change in the declinations can probably be explained as follows. Like all other stereoscopic space interpretations it is based on the disparity of the images in the two eyes. Imagine a surface not normal to the line of vision, for instance like a table looked at obliquely. The disparity of the images of objects in the near and far ends of such a surface as seen by each eye increases as the surface is brought nearer the eyes, decreases as it is removed. That is, our judgment of the distance of the surface is determined by the magnitude of this disparity. So, artificially changing this disparity causes a fixed surface to change its apparent position. If the surface is normal to the line of vision, like a wall, the basis for this phenomenon does not exist. If the surface is overhead, like a ceiling looked at obliquely, the basis for the phenomenon exists but opposite rotations of the vertical meridians are necessary to produce the same directional changes in distances that result when looking, for example, at the top of the table.

These phenomena are easily demonstrated with meridional size lenses of, say, 2 percent to 3 percent, held first R.E. axis 45°, L.E. axis 135°, then R.E. axis 135°, L.E. axis 45° and observing the floor and ceiling. It is believed that a scientific investigation of their bearing on the function of vision and their correlation with other ocular anomalies may lead to some fruitful findings.

The magnitude and direction of all of the above-described false interpretation of the position of surfaces, resulting from induced differences in the relative sizes of the ocular images and declinations, correspond with surprising accuracy to the theoretically calculated results that would be expected.

The question arises, does a similar false stereoscopic interpretation of the position of surfaces exist in cases in which the aniseikonia or difference in size of the ocular image is of long standing? Or do those who have aniseikonia learn through experience to make compensation for the false impressions they receive?

To answer this question all the aniseikonic patients who come to the clinic are being tested on the Tilting Field after their aniseikonia has been measured and corrected on the ophthalmo-eikonometer. To date 65 patients have been so tested. Not one of these 65 showed normal stereoscopic sense of depth; i.e., not one could set the tipping plane level. To 63 patients, or in 97 percent of the cases, the plane appeared tilted in the direction indicated by his aniseikonia; to 40, or in 62 percent of the cases, the plane appeared tipped to the approximate magnitude of the aniseikonia; i.e., the findings did not differ by more than 1.00 percent. To 22, or in 33 percent of the cases, the variation was between 1.00 percent and 3.00 percent, but in the same direction. In one case which we have been unable to recheck, the tipping was in the opposite direction.

It is interesting to note that 31 patients, or 48 percent, reported marked relief, and 29 percent partial relief from wearing their iseikonic prescriptions. Eight, or 12 percent of the cases, were failures, and 7, or 11 percent, were indeterminate.

These results were so striking that it is hoped that instruments built on the principle of the Tilting Field can be useful for clinically determining and correcting aniseikonia.

As stated, the detail on the tilting surface must be irregular in its arrangement. If the pattern is regular the above-described apparent tipping does not result from changing the size of the ocular images. This is explained on the ground that the regular pattern enables the observer to judge correctly the position of the surface through perspective interpretation. Preliminary experiments have been made to determine the amount and nature of the regularity of pattern necessary to cause the observer's perspective judgment to become dominant. The test consisted in placing various patterns on the tilting field set in its normal position. These were viewed by an observer in whom aniseikonia had been induced by size lenses and to whom, therefore, the table appeared tipped. If the pattern was such as to give a basis for judging its position by perspective, as two lines at right angles to each other, the pattern would appear as horizontal while the table still appeared to be tipped. But if the pattern gave no such basis for perspective judgment as a single straight line, it appeared to be tipped with the table.

In conclusion, it can be stated that through their perspective sense, which is affected by aniseikonia only very slightly or not at all, persons interpret the orientation of surfaces, planes, and groups of objects correctly.

Through their stereoscopic sense, persons with aniseikonia falsely interpret the orientation of surfaces, planes, and groups of objects considered as a whole. The extent to which their total visual judgment is affected by their false stereoscopic sense depends upon the predominance of perspective features in the field of view.

References

[1] Ames, A. Jr., Ogle, K. N., and Gliddon, G. H. Corresponding retinal points, the horopter and size and shape of ocular images. Jour. Optical Soc. of Amer., 1932, v. 22, November, p. 538.

Ogle, K. N. Analytical treatment of the longitudinal horopter; Its measurement and application to related phenomena, especially to relative size and shape of the ocular images. Jour. Optical Soc. of Amer., 1932, v. 22, December, p. 666.

Discussion. Dr. William H. Crisp: In cases reported as successful, was the general refractive correction modified at the same time that the iseikonic modification in the lenses was made?

Professor Ames: In general, the procedure in the clinic in all cases is first to determine whether relief can be obtained by correcting the refractive condition. If relief is not obtained from refractive correction, the iseikonic condition is determined. In quite a few cases, changes in the relative refractive condition of the two eyes take place when the aniseikonia is corrected. This, in turn, has to be corrected. It is most important that the refraction of the two eyes be carefully balanced. Whether or not the conjugate point for both eyes is a little nearer or farther is not so important.

Dr. Crisp: If I may amplify the question further, if a change is made in the refraction at the same time you add the iseikonic correction, how can you be sure which influence was responsible for the comfort of the patient?

Professor Ames: In the first place, there are many patients that have no error of refraction with whom successful results are obtained alone by size corrections. Secondly, in the cases where the refraction is changed at the same time the aniseikonia is corrected, the amount of the refractive change is too small, i.e., usually around 0.25 or 0.37 D., to account for the marked relief obtained.

Dr. William H. Wilmer: I have noticed in the practical correction of aniseikonia an instance in which, for example, a person has an axis of the refractive cylinder at 85° and the aniseikonic lens is put at 90°. I would like an explanation of that.

Professor Ames: The reason for this is a practical one. Up to the present the lenses that are used for determining meridional size differences consist of a telescopic plus-minus combination of cylinders, in which the front component moves relative to the rear one. To avoid introducing astigmatism, the axes of these two components must be very accurately lined up, which is insured by stops on the lenses. Up to the present, we have not devised a good mechanical way to have more than two stops, one at 90° and one at 180°, which limits the placing of the meridional size lenses to these two axes. We would prefer to be able to set these axes in any meridian and are developing a new mechanism by which we expect to be able to do so.

Dr. Clyde Clapp: Which gives the larger image, a flat lens of 6 diopters, i.e., with inside curve of —1.25 D. or a periscopic lens of the same power with an inside curve of —12.00 D.?

Professor Ames: I am sorry to say I cannot give you an answer offhand. The problem of the size effectivity of lenses is a very difficult one, requiring a knowledge of higher mathematics and lens design for its thorough comprehension. A part of our staff has for a number of years been devoting their entire time to this problem. Mr. Imus, who is here with me, can answer your specific question.

Mr. Imus: The magnification of the lens of +6 D. with inside curve of —12.00 D. would be greater than that of the lens of +6 D. with an inside curve of —1.25 D.

Dr. Frederick H. Verhoeff: I would like to ask, were the results different when fixation was kept constant from those found when fixation was allowed free play?

Professor Ames: Dr. Herzau in Dr. Tschermak's laboratory did some work on determining the position of the horopter with and without constant fixation. He found only second-order variations.

Dr. Theodore A. Terry: I wonder, Professor Ames, if you have noticed any evidence of a psychological effect either from the examination or from the treatment, or both? That is, people who have apparently responded and probably had a relapse after a while? What bearing do you think the psychological factors have in the matter?

Professor Ames: This question, I consider, is one that a medical man is best qualified to answer. But I would say that there is no question but that a psychological effect does result from putting a patient through the clinical examination for aniseikonia, just as it does in any other medical examination using complicated instrumentation. But that this has been an important factor in bringing about the results that have been obtained can, I think, be absolutely denied. Anyone who has been present throughout the treatment of a series of aniseikonic patients would, I believe, be of the same opinion. Dr. Bielschowsky of Breslau, Germany, whom many of you know, has worked with us in our clinic and laboratory for six months during the last year. He would, I believe, answer your question as I am answering it.

HV2330 AMES ADELEBERT JR. c.1
A ANISEIKONIA-A FACTOR IN THE
FUNCTIONING OF VISION.

Date Due

HV2330 c.1
A
AMES, ADELBERT JR.
AUTHOR
ANISEIKONIA-A FACTOR IN THE
TITLE
FUNCTIONING OF VISION.

DATE DUE	BORROWER'S NAME

PAMPHLET BINDERS
This is No. 1527
also carried in stock in the following sizes

	HIGH		WIDE		THICKNESS		HIGH		WIDE		THICKNESS
1523	9	inches	7	inches	½ inch	1529	12	inches	10	inches	½ inch
1524	10	"	7	"	"	1530	12	"	9⅛	"	"
1525	9	"	6	"	"	1932	13	"	10	"	"
1526	9¾	"	7⅛	"	"	1933	14	"	11	"	"
1527	10½	"	7⅜	"	"	1934	16	"	12	"	"
1528	11	"	8	"	"						

Other sizes made to order.

MANUFACTURED BY
LIBRARY BUREAU
Division of REMINGTON RAND INC.
Library Supplies of all kinds